ARRAY DETECTORS

Fabrics that "See": Photosensitive Fiber Constructs

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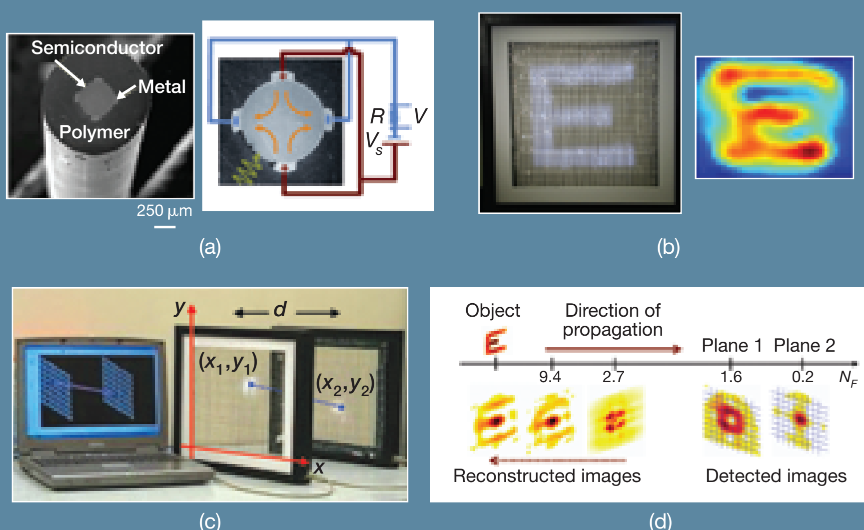
Textile fabric has provided essential protection from the environment for millennia—but it hasn't had much to offer in terms of optical functionality. Now, in a recent paper, we demonstrated that lightweight, flexible, photosensitive polymeric fibers woven into arrays can "see," potentially allowing for optical functionality in fabrics.[1]

The fibers, produced by a thermal drawing procedure, have a photosensitive core (an amorphous semiconducting chalcogenide glass) surrounded by a transparent polymer and in contact with four metal electrodes that extend the full length of the fiber, as shown in part (a) of the figure.[2] The fibers will produce an electrical signal that is proportional to the line integral of the intensity of an incident optical field. Thus, a 2D array constructed of these fibers can reconstruct the amplitude of an arbitrary incident intensity distribution from rotated versions of the distribution using the Radon transform (b).[1,3]

Further, such an array is essentially transparent, and one may stack cascaded arrays to extend the optical functionalities. An example is shown in the figure, part (c), where two planar arrays separated by a distance d detect the position *and* direction of an optical beam. The flexibility of the fibers also allows us to construct novel array topologies such as that of a closed sphere that detects the path of a beam of light over the full 4π steradians of the ambient environment.[1]

Finally, two planar arrays that detect the intensity distributions in two planes can reconstruct both the amplitude and the phase of an incident wave front using the phase retrieval algorithm.[1,4] We demonstrate the feasibility of this approach in a lensless imaging experiment, where we propagate the reconstructed complex field distribution backwards to estimate the illuminated object (d).

We have also recently demonstrated 2D arrays constructed of thermally sensitive fibers.[5] Combining photosensitive and thermally sensitive fibers in a fabric will lead to clothing that sees and also senses the environment.



(a) (*Left*) An SEM micrograph of a cross-section of a photosensitive fiber. (*Right*) Fiber electrodes connected to an external circuit and electric field lines (yellow arrows). The scale bar is 250 µm. (b) A 32 x 32 fiber array (clear dimensions 24 x 24 cm^2) reconstructs the image of a letter "E" formed using a white light source illuminating a transparency (the image seen in the left panel is formed on a white sheet placed behind the transparent array). (c) Two planar fiber arrays can detect and reconstruct the beam path in 3D. (d) Non-interferometric lensless imaging using two fiber arrays. An "E" (750 x 750 μm^2) is illuminated with a laser, and the propagating diffracted field amplitude is obtained at two locations with fiber arrays (N_F is the Fresnel number). The phase-retrieval algorithm is used to obtain back-propagated images.

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References

1. A.F. Abouraddy et al. "Large-scale optical-field measurements with geometric fibre constructs," Nature Mater. **5**, 532-6 (2006).
2. M. Bayindir et al. "Metal–insulator–semiconductor optoelectronic fibres," Nature **431**, 826-9 (2004).
3. A.C. Kak and M. Slaney. *Principles of Computerized Tomographic Imaging*, IEEE Press, N.Y. (1988).
4. J.R Fienup. "Phase retrieval algorithms: a comparison," Appl. Opt. **21**, 2758–69 (1982).
5. M. Bayindir et al. "Thermal-sensing fiber devices by multimaterial codrawing," Adv. Mater. **18**, 845–9 (2006).